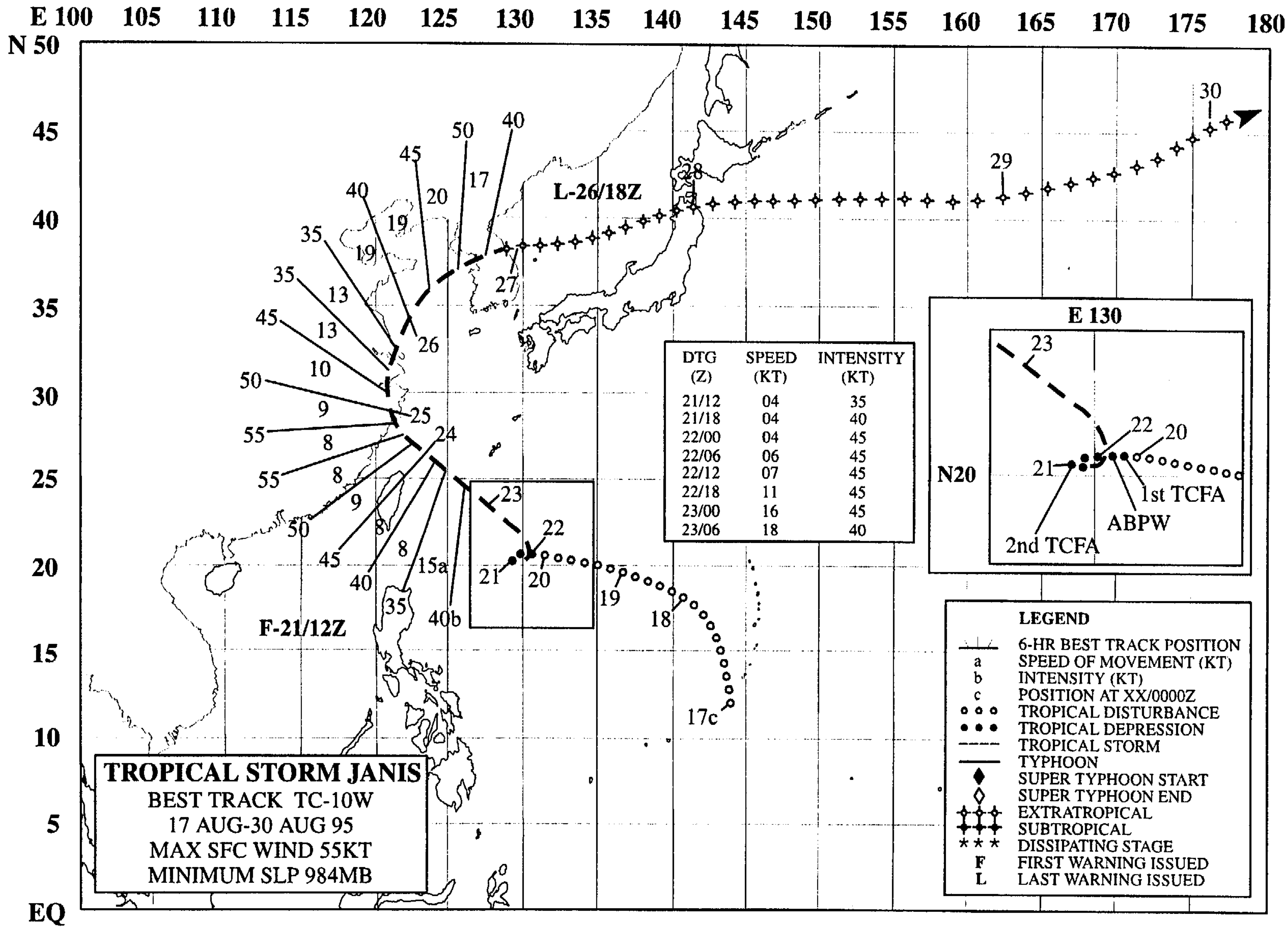
TROPICAL STORM JANIS
BEST TRACK TC-10W
17 AUG-30 AUG 95
MAX SFC WIND 55KT
MINIMUM SLP 984MB
F-21/12Z
L-26/18Z
DTG (Z) | SPEED (KT) | INTENSITY (KT)
21/12 04 35
21/18 04 40
22/00 04 45
22/06 06 45
22/12 07 45
22/18 11 45
23/00 16 45
23/06 18 40
E 130
N20
1st TCFA
2nd TCFA
ABPW
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM JANIS (10W)

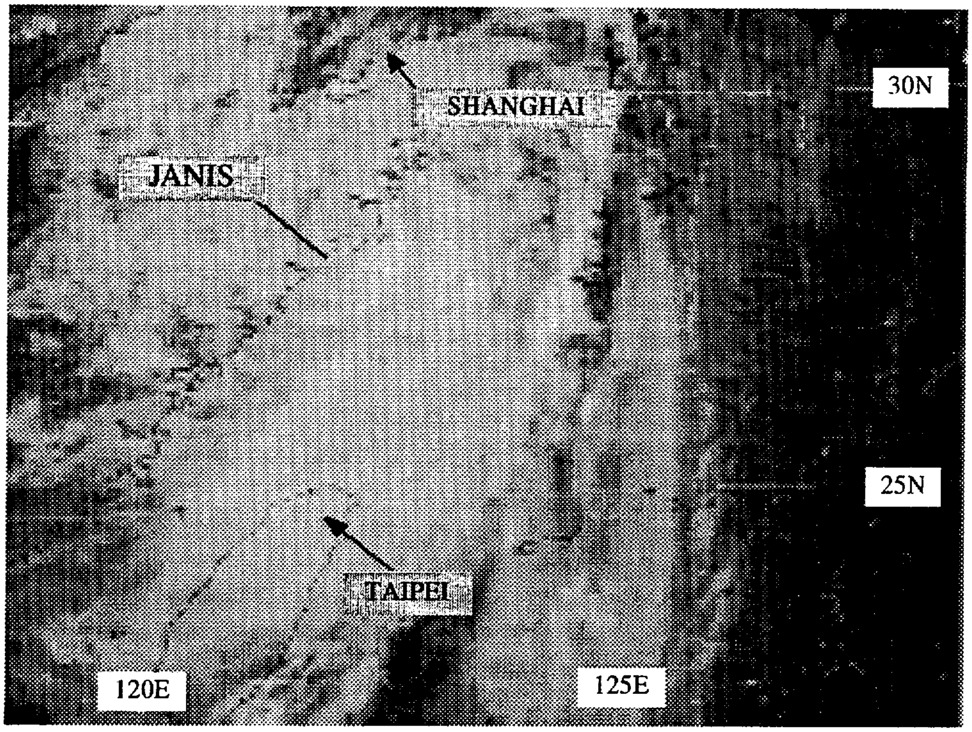

Figure 3-10-1 Janis makes landfall in eastern China shortly after attaining its peak intensity of 55 kt (28 m/sec) (250031Z August visible GMS imagery).

I. HIGHLIGHTS

Forming in a monsoon trough that extended from Asia into the Philippine Sea, Janis moved northwestward and merged with Tropical Depression 11W. In an unusual case of tropical cyclone merger, the larger Janis actually lost much of its deep convection and became less organized as it merged with the smaller Tropical Depression 11W. Subsequent to the merger, all deep convection was lost, but later regenerated as the system moved northward east of Shanghai (Figure 3-10-1). Moving eastward across the Yellow Sea, Janis made landfall in central Korea near Seoul. Heavy rain and winds associated with Janis had a significant impact on South Korea.

II. TRACK AND INTENSITY

During the second week of August, there was relatively little deep convection throughout the tropics of the western North Pacific. On or about 16 August, deep convection had increased across the Philippine Sea and eastward into Micronesia. Several clusters of enhanced convection were distributed along this cloud band in a complex association with a chain of TUTT cells to the north. The tropical disturbance that became Janis had a rather ambiguous start. The first mention of the tropical disturbance that most probably became Janis appeared on the 180600Z August Significant Tropical Weather Advisory. This tropical disturbance moved northwestward and slowly became better organized. The following excerpts from the Deputy Directors' unofficial log provide an insight into the techniques and thought processes used by JTWC forecasters to construct the sequence of warnings on Janis (note the use of concepts developed by Carr and Elsberry (1994) in their systematic approach to tropical cyclone forecasting):

"[Tropical Cyclone Formation Alert] TCFA #1 [issued at 200330Z August], circulation around 21N 132E, Broad area of deepening convection starting to show cyclonic turning."

"TCFA #2, [issued at 210300Z August] Two distinct circulation centers: 19N 133E and 20N 129E. Broad circulation, [it] remains unclear which of these will [develop]. BUT one of them will."

"Warning #01: 21/12Z: Dvorak 2.0 and synoptic obs of 20 and 25 knots about the circulation center near 20.4N 129.9E prompts this warning [on Tropical Depression 10W]. NOGAPS anal indicates model has fair to good initialization despite not having the circulation. 700 and 500 mb indicates slow westward motion through 24-36 hours followed by increasing northward motion out to 72 hours. Models indicate building of the ridge, already analyzed, to the SE of the circulation. Appears to be a classic N2 [see discussion of the Systematic Approach] and forecasting a north-oriented track after about 24 hours of slow westward drift, while consolidating. Intensification 1T/day. Everything looks favorable; in addition there is a TUTT cell to NW that should support outflow on NE quadrant of the TC."

"Warning #02: 21/18Z: [Upgraded to TS (JANIS) based on synoptic and satellite data. Still N2 forecasting very slow westward drift while system consolidates followed by northward acceleration at 36 - 48 hours."

"Warning #03: 22/00Z: NOGAPS 21/12Z continues to build ridge from south along east side of storm up to the [subtropical ridge]. Modifying the [subtropical ridge] in classic N2 and north-oriented motion. However the model does not build very strong [outer wind] asymmetries . . . as expected. This may be a factor of large TC actual size, but NOGAPS not hanging onto the vortex yet. Still forecasting for slow westward now for 12-24 hours, followed by acceleration to northward. Okinawa in danger. Intensification remains 1T/day. NOTE: [Mesoscale Convective Complex] developing about 350 nm NNW of Janis. This is [associated with] the TUTT cell, but may . . . support cyclogenesis. Issuing TCFA on it. Potentially 11W."

"Warning #05: 22/12Z: TS Janis has slowly moved back to the east as it undergoes binary interaction with TD 11W. Intensification is stalling but that should be temporary. Forecasting for slow ENEward motion followed by . . . NWward track thru period. This places Okinawa directly in the path of Janis."

"Warning #07: 23/00Z RELOCATED: Janis absorbed TD 11W but did not execute as long a ENEward track as forecasted. Janis is now tracking NWward at about 16 knots. NOGAPS no longer supports north-oriented pattern. NWward steering asymmetries are evident early in prog series and weaken thru 72 hours. Now forecasting for a more classic recurver scenario. NWward track thru 48 hours followed by recurvature towards Korea. Intensification should resume but current rate does not support 1T/day. Forecast TY by 25/00Z with 75 knots at 72 hours off the southern coast of Korea."

"Warning #09: 23/12Z: Janis is tracking Nward at 13 knots and intensifying slowly. NOGAPS fields do not clearly [indicate] the steering flow . . . 500 mb 20 knot, Nward asymmetries are evident thru 48 hours. By 72 hours only a small finger of 20 knot [wind extends] north towards the storm circulation. This could indicate northward motion and weakening, OR the storm could move over China and dissipate. Forecast is similar to previous: NWward out to 25/00Z followed by recurvature towards Korea. [However] losing confidence in this philosophy. System may go over land in China and dissipate."

On 25 August, Janis made landfall in eastern China near Wenzhou. Moving northward over land, the system weakened. Approximately six hours after passing near or over Shanghai, Janis turned to the northeast and moved into the Yellow Sea; its intensity had fallen to 35 kt (18 m/sec). Once over water again, Janis began to re-intensify as it turned more eastward and accelerated toward the Korean peninsula. Janis made landfall near Seoul at approximately 261500Z. Peak winds at the time of landfall were estimated to have been 50 kt (26 m/sec). The JTWC issued the final warning valid at 261800Z as Janis became extratropical while passing over the mountains of Korea. The system continued as an extratropical low — with gales — as it crossed the Sea of Japan.

III. DISCUSSION

a. *The "Systematic Approach" to tropical cyclone track forecasting*

As seen in some of the Deputy Director's log entries listed above, the rationale for the forecast is couched in terms of a forecast scheme developed by Carr and Elsberry (1994). Carr and Elsberry developed what they term "a systematic and integrated approach to tropical cyclone track forecasting" (hereafter referred to as the "Systematic Approach"). The "Systematic Approach" is intended to address some deficiencies in the current forecasting process. It employs two important knowledge bases: (1) a comprehensive set of conceptual models (Part I) to assist the forecaster in characterizing the tropical cyclone environment; and, (2) a compilation (Part II) of the traits and biases of the numerical tropical cyclone prediction models organized in accordance with the conceptual model knowledge base. The conceptual models developed in Part I relate tropical cyclone motion to tropical cyclone structure (both intensity and size); and, most importantly, to tropical cyclone/environment transformations, by which environmental patterns (and thus the attendant steering) may be significantly altered by the presence of the tropical cyclone.

The set of conceptual models is organized into three general groups that are further organized into two subsets based on scale: synoptic patterns (classifications of the large-scale environment surrounding the tropical cyclone based on the existence and orientation of various synoptic features such as cyclones, anticyclones, ridges, and troughs); and, synoptic regions (identification of smaller areas within the synoptic patterns where certain characteristic directions of environmental steering may be expected to occur).

JTWC forecasters have begun to use and evaluate Carr and Elsberry's "Systematic Approach". The comment, "modifying the [subtropical ridge] in classic N2 and north-oriented motion", that appeared in the log entry concerning Warning #3 is based upon use of the "Systematic Approach". The N2 pattern is a specific environmental flow pattern identified by Carr and Elsberry (Figure 3-10-2) that is associated with north-oriented motion. Carr and Elsberry's scheme is still in the process of development, but it is also being used by JTWC forecaster's even as the knowledge base is established and refined; thus, a

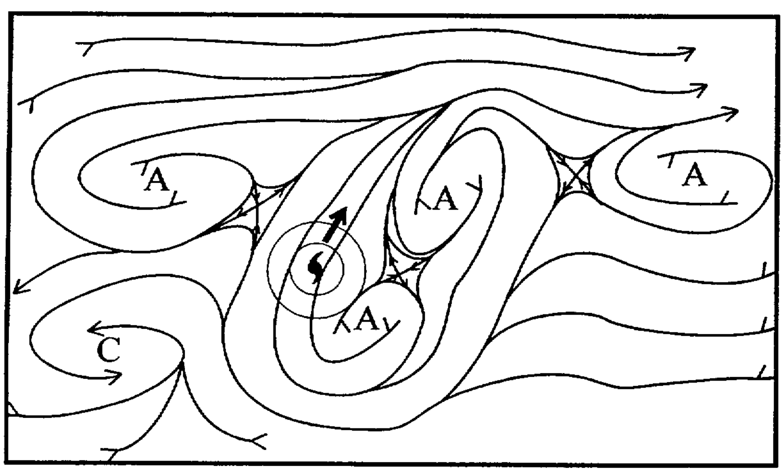

Figure 3-10-2 Schematic illustration of the wind flow at the 500-mb level in the synoptic pattern N2 that is favorable for north-oriented tropical cyclone motion. (Adapted from Carr and Elsberry, 1994).

healthy feedback between the JTWC and the research community has been established. The reader is referred to Carr and Elsberry (1994) for a complete treatment of the "Systematic Approach".

b. *Tropical cyclone merger*

Janis merged with Tropical Depression 11W. Tropical cyclone merger is one possible outcome of the mutual interaction of spatially proximate tropical cyclones. The interaction of two adjacent tropical cyclones is often referred to as the Fujiwhara effect after the pioneering laboratory and observational studies of Fujiwhara (1921, 1923, and 1931). Fujiwhara demonstrated that the relative motion of two adjacent cyclonic vortices was composed of cyclonic orbit around their centroid, coupled with a mutual attraction. The rate of orbit steadily increases as the vortices spiral inward toward one another and eventually the two vortices coalesce into one vortex located at the centroid (i.e., the geographical mid-point between the two tropical cyclones).

The observed behavior of two adjacent tropical cyclones usually differs from the classical Fujiwhara effect in several aspects. Prominent among these is the usual failure of tropical cyclones to merge. Because of these differences, the interaction between two tropical cyclones is usually called binary interaction. Lander and Holland (1993) developed a generalized model of binary interaction, and showed that the classical Fujiwhara model of converging cyclonic rotation about a centroid followed by merger is rarely observed. Rather, the most common outcome of binary interaction is a mutual cyclonic orbit of the centroid by each tropical cyclone at a fairly constant separation distance followed by a sudden escape wherein the mutual cyclonic orbit ceases and the tropical cyclones move apart.

Though less frequent, the merger of two tropical cyclones usually involves the destruction (i.e. loss of deep convection) of one member of the binary pair. The remnants of the destroyed tropical cyclone are

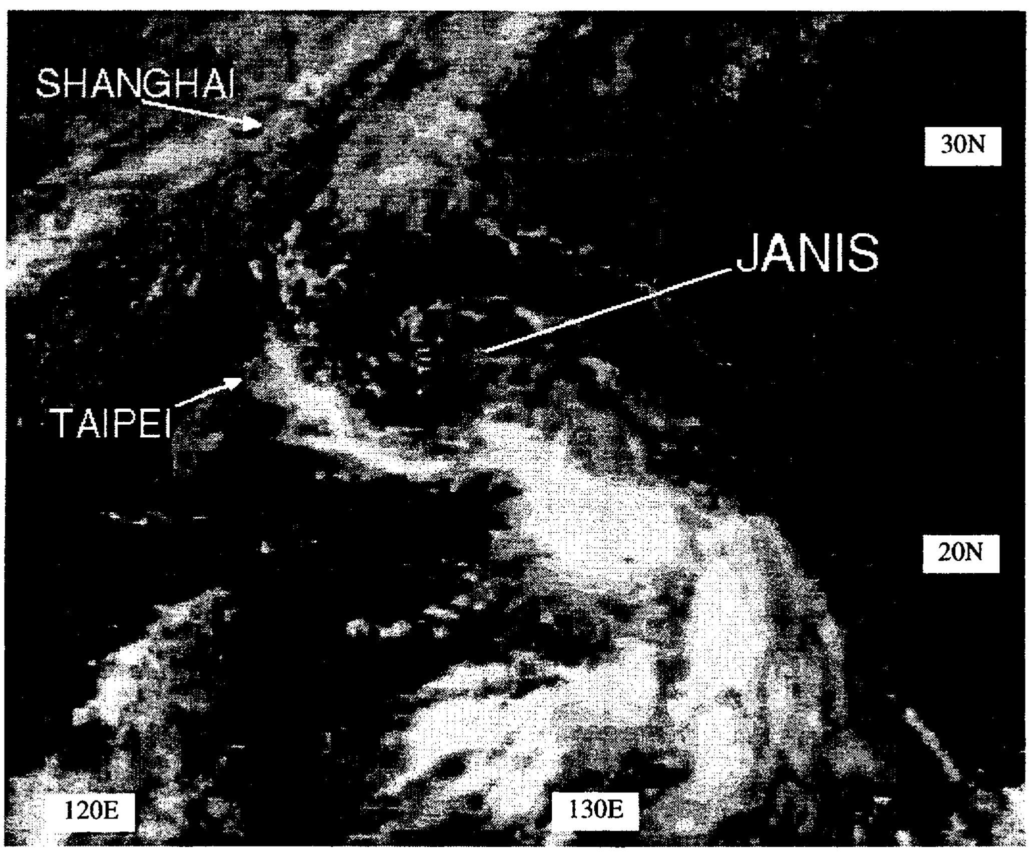

Figure 3-10-3 After Janis had absorbed the circulation of Tropical Depression 11W, the amount of deep convection near the center of the combined vortex decreased considerably (230231Z August visible GMS imagery).

then swept into the circulation of the remaining one. The merger of Janis with Tropical Depression 11W was somewhat unusual in that, as the merger was taking place, each system lost much of its deep convection, and in the case of the larger and better organized Janis, the deep convection also lost much of its organization. Ultimately, Tropical Depression 11W was absorbed into the larger circulation of Janis, but after the merger, most of the deep convection was lost in the combined vortex (Figure 3-10-3). Later, convection became reestablished near the low-level circulation center (Figure 3-10-4).

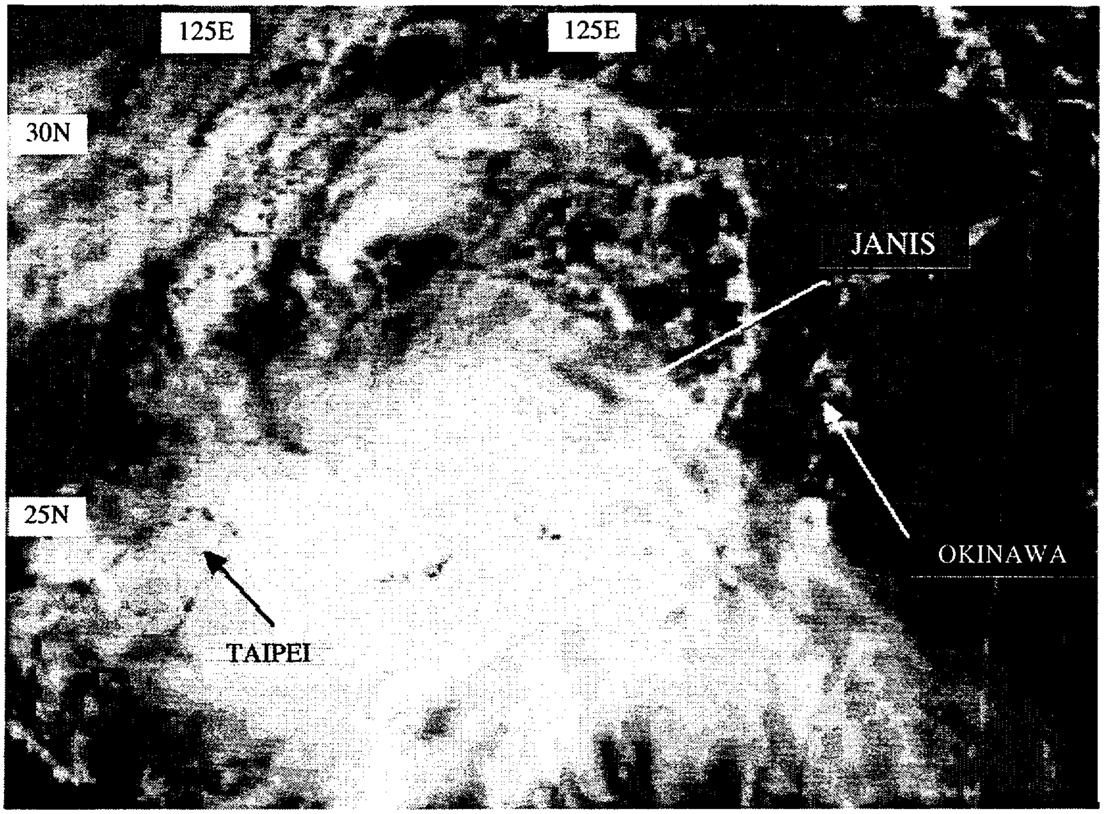

Figure 3-10-4 Deep convection became reestablished near the center of Janis approximately 24 hours after its merger with Tropical Depression 11W (232331Z August visible GMS imagery).

IV. IMPACT

After brushing past Shanghai, Janis turned eastward, crossed the Yellow Sea (Figure 3-10-5), and then made landfall in Korea just north of Seoul. At Osan Air Base, a wind gust of 52 kt (27 m/sec) broke the standing record of 51 kt (26 m/sec) recorded in 1968. The record wind, accompanied by heavy rain, forced the evacuation of two fighter squadrons, uprooted hundreds of trees, knocked down power lines, and left more than 65 buildings without power for more than 12 hours. Elsewhere in Korea, reports of 45 people dead and nine missing were received. Thirty of those killed were crushed by landslides. The rest died when they were swept away by strong currents in streams or struck by lightning. One person died when a train derailed on a bridge over a swollen river. Torrential rains associated with Janis left more than 22,000 people homeless and caused damage in South Korea totaling about $US 428.5 million, the largest rain related disaster in the nation's history. As Janis passed over northern Japan, wind gusts in the high 40s were recorded at many stations. No reports of significant damage or injuries were received from Japan.

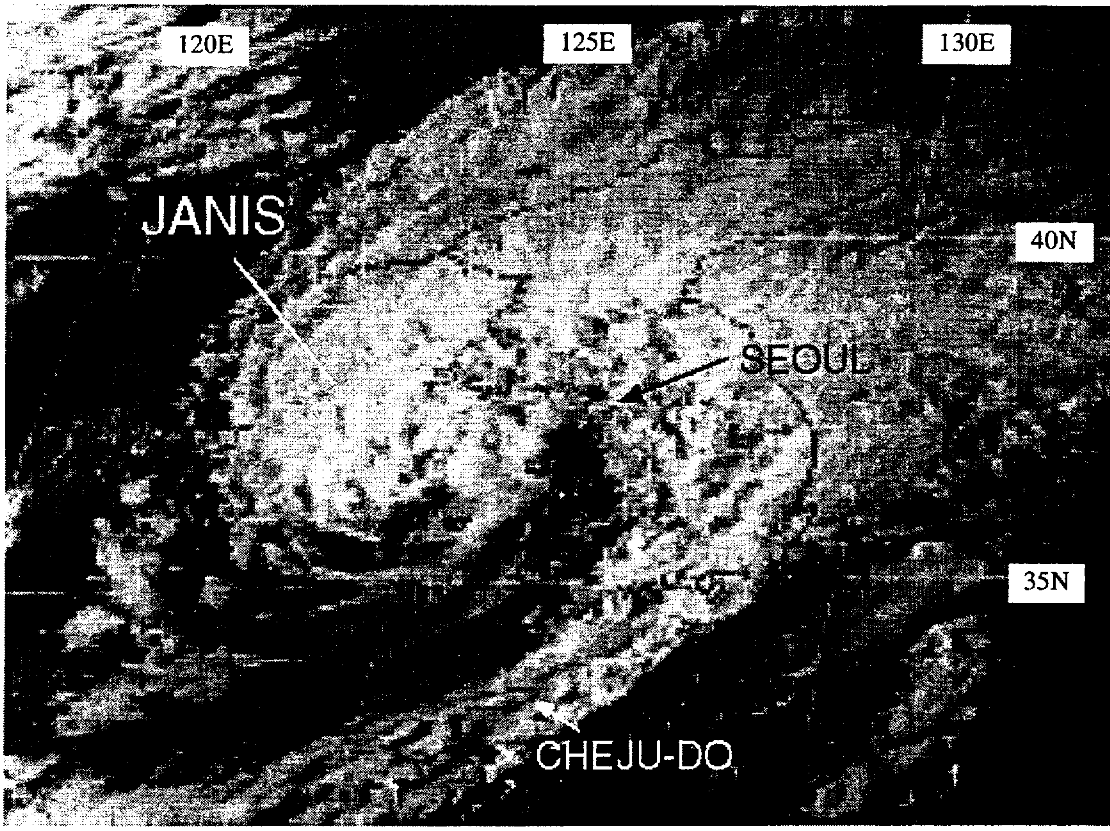

Figure 3-10-5 Janis closes in on the Korean peninsula (260831Z August visible GMS imagery).